Technical Description for the Office Model

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Data Source

Energy consumption and building characteristics data for the analysis of office buildings were obtained from the U.S. Department of Energy, Energy Information Administration's (EIA) 1992 and 1995 Commercial Buildings Expenditures and Consumption Survey (CBECS).

Data Set and Basic Filters

To yield a data set as large as possible, the 1995 CBECS data set was combined with the 1992 data set resulting in a total of 2,671 office records. Basic filters were applied to both data sets for the purpose of obtaining a more homogenous data set and are presented below. Those data records that did not meet any of these criteria were removed from the analysis.

Data Filters

Description	CBECS Variable	Criteria
Gross Building or Facility Area (ft^2)	SQFT	> 4,999 and < 1,000,000
Weekly Hours of Use	WKHRS	> 29
# of Months in Use out of past 12	MONUSE	> 10
Occupant Density	NWKER/(SQFTx1000)	> 0.3 and < 10.0
# of Personal Computers	PCTERM	> 0
Annual Electricity Consumption (Btu)	ELBTU	> 0
Annual Electricity Consumption (Btu)	ELBTU	< 10,000,000,000,000
HDD + CDD	HDD65, CDD65	> 0
Principal Building Activity	PBA	= 2 (Office)

Applying the filters above resulted in 1,835 records by combining the 1992 and 1995 CBECS data sets. The building area filter, SQFT < 4,999, resulted in the removal of the majority of records. Records with floor area greater than 1,000,000 ft^2 were eliminated due to a high degree of manipulation of the actual data within CBECS to mask the identity of the building.

Dependent Variable

The basis of the regression, that is, the dependent variable chosen for the regression was the annual source energy use intensity, Source EUI, where annual source energy was measured in kBtu/year. Energy intensity, typically Site not Source, is a commonly used and understood means to characterize and compare building energy performance amongst groups of buildings. Thus, it was determined that results would be provided to the users in terms of the more common site energy intensity by simply converting the Source EUI to Site EUI using the building's fuel mix and standard Site-Source conversion factors. A more detailed description is provided in the section on Assessing Performance near the end of this document.

Independent Variables

After examining the correlation of hundreds of CBECS variables to source energy intensity, the following independent variables were more closely examined for their significance and correlation with the dependent variable as well as with the other independent variables.

HDD	heating degree days
CDD	cooling degree days
OccDens	number of workers during main occupancy per 1,000 ft^2 of gross building area
PCDens	number of personal computers per 1,000 ft^2 of gross building area
Area	gross building square footage
Hours	average weekly hours when building is at least 50% occupied
Floors	number of levels in the tallest section of the building

Weighting Factors

The stated purpose of CBECS is to develop and publish estimates of population values. The CBECS survey sample is designed so that survey responses can be used to estimate characteristics of the entire stock of commercial buildings in the United States (EIA, CBECS 1995). Basic sampling weights that relate sampled buildings to the entire stock of commercial buildings are calculated for the CBECS sample. While sampling weights – or weighting factors – are necessary to estimate characteristics of the entire stock of U.S. commercial buildings, they are not necessary to perform meaningful regression analyses. Thus, the CBECS weighting factors were not used in the analysis of the Office regression modeling.

Source Energy

The analysis relied upon source energy consumption versus the site energy consumption provided in CBECS. A one-page discussion regarding the use of the source energy convention versus the site energy convention can be viewed and downloaded via www.energystar.gov. The following conversion factors were used to obtain source energy consumption from the site energy consumption:

Fuel Type	Site (kBtu)	Source (kBtu)
Electricity	1	3.0129
Natural Gas	1	1.024
Fuel Oil	1	1
Steam	1	1.38
Hot Water	1	1

Regression Results

The objective of the analysis was to determine the significant drivers or building characteristics of Source EUI. Prior to undertaking this analysis, the explanatory power of the simple relationship of annual source energy consumption to gross building area was examined.

A simple regression model was examined with annual source energy consumption, Source, as the dependent variable and the natural log of gross building area as the independent variable. The analysis revealed an R-squared for this simple model to be 0.65. Thus the inclusion of other variables in the model effectively means that the regression model is attempting to explain the remaining 35% ([1-0.65]*100) since the square foot term is already explaining 65% of the variability in source energy use.

Table-1 presents the results of the regression analysis. The independent variables used were LnAREA, CDD, Hours, OccDens, and PCDens. Each variable was found to be significant by the standard statistical definition where the T-statistic is greater than +/- 2.0.

Table-1 Regression Model Results

Dependent Variable: Source EUI
Method: Least Squares
Sample: 1 1835
Included observations: 1835

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-42.215	29.399	-1.436	0.1512
LnArea	14.967	3.063	4.886	0.0001
CDD	0.012	0.004	3.009	0.0027
Hours	0.517	0.109	4.732	0.0001
OccDens	16.766	2.312	7.250	0.0001
PCDens	9.759	1.389	7.027	0.0001

R-squared	0.1334	Mean dependent var	201.7
Adjusted R-squared	0.1310	S.D. dependent var	1098.96
S.E. of regression	2216.21	F-statistic	56.326
		Prob(F-statistic)	0.0001

Table-2 presents the basic statistics – mean/median, minimum/maximum, and standard deviation – for each of the model variables.

Table-2 Basic Statistics, Model Variables

Variable	# of Obs	Mean
Source EUI	1835	201.7
LnArea	1835	9.55
CDD	1835	1109
Hours	1835	55.3
OccDens	1835	2.31
PCDens	1835	2.12

Look-Up Table

Table-4 in the Appendix is the look-up table of EPRs from 1 to 100 and Source EUI values. The column of Actual Source EUI represents the simple adjusted Source EUI values obtained in applying the regression model to the CBECS filtered data sets. Thus, these values represent the normalized Source EUI values on a percentile basis. The column of Fitted Source EUI takes the normalized Source EUI values and fits them to a gamma distribution. The purpose of fitting the Source EUI values to a gamma distribution is to reduce the likelihood of "clustering" of Source EUI values about various EPRs In fitting the Actual Source EUI the value corresponding to an EPR of 75 – the minimum threshold for ENERGY STAR – is held constant. Once done, the values in the Fitted Source EUI column corresponding to the EPRs of 1 to 100 now represent the nominal look-up table used to assess an individual building's performance..

Assessing Performance

To assess the performance of a building via the Energy Performance Rating, two calculations are made upon the user entering in the requisite data. First, as explained in the Weather Normalization file (downloadable at www.energystar.gov), the user's actual annual source energy intensity, in kBtu/ft^2-yr, is weather normalized to reflect the annual source energy intensity the building would have seen in a normal (i.e. 30-year average) weather year. In the second calculation, the regression model equation is used to calculate a predicted Source EUI value based on the operating characteristics entered by the user. This Predicted Source EUI is then divided by the Mean Source EUI of the regression model, which yields an adjustment factor. The adjustment factor is then multiplied to each of the Fitted Source EUI values corresponding to EPRs from 1 to 100 to provide a range of Customized Source EUI values. Finally, to calculate the EPR, the building's weather normalized Source EUI is compared to the table of Customized Source EUI values.

Table-3 is intended for use with the following example to illustrate how an EPR is determined for a given building. In this example, the actual Source EUI was weather normalized down approximately 2%; in essence meaning that over the course of the year in which the building's energy consumption was reported the building "experienced" a net 2% more severe weather year than normal.

Example Office

Area	=	200,000 ft^2
CDD	=	1582
Weekly Hours	=	65
# of Workers	=	450
# of PCs	=	400

Actual Source EUI = 134.5 kBtu/ft^2-yr

Weather Norm. Source EUI = 131.8 kBtu/ft^2-yr ⟵

Regression Equation

Source (kBtu/year) = $C_0 + C_1$ Ln(Area) + C_2 CDD + C_3 Hours+ C_4 OccDens + C_5 PCDens

Source (kBtu/year) = - 42.215 +14.967*Ln(Area) + 0.012*CDD + 0.517*Hours + 16.766*OccDens + 9.759*PCDens

Predicted Source EUI = 250.3 kBtu/ft^2-yr
Mean Source EUI = 201.7 kBtu/ft^2-yr

Adjustment Factor = (250.3/201.7)
= 1.24

Table-3 Determining Energy Performance Rating

EPR	Fitted Source EUI (kBtu/ft^2-yr)	Adjustment Factor	Customized Source EUI (kBtu/ft^2-yr)
100	47.4	1.24	58.8
99	56.5	1.24	70.2
98	63.1	1.24	78.2
…	…	…	…
…	…	…	…
…	…	…	…
85	104.7	1.24	129.9
84	107.0	1.24	132.7
83	109.2	1.24	135.4
…	…	…	…
…	…	…	…
…	…	…	…
1	537.2	1.24	666.1

Note that when this model is placed onto the production site with the Energy Performance Rating software tool, users can include other space types to further characterize their building. These space types include K-12 schools, Supermarkets, Hotel/Motel, Hospitals, computer rooms, garage space, and parking lots. With the exception of parking lots, these other space types, if used to characterize the building having office space, are incorporated into the Energy Performance Rating by using weighted averages. If defined by the user, the energy impact associated with parking lots is simply added to the customized look up table.

Appendix

Table-4 Energy Performance Rating, Adjusted Source EUI, and Fitted Source EUI

EPR	Actual Source EUI (kBtu/ft^2-yr)	Fitted Source EUI (kBtu/ft^2-yr)		EPR	Actual Source EUI (kBtu/ft^2-yr)	Fitted Source EUI (kBtu/ft^2-yr)
100	50	47.42		50	172	172.91
99	61	56.59		49	174	174.89
98	63	63.05		48	175	176.89
97	64	68.25		47	176	178.90
96	74	72.70		46	177	180.94
95	75	76.65		45	178	182.99
94	77	80.23		44	179	185.08
93	79	83.55		43	184	187.18
92	82	86.64		42	186	189.31
91	83	89.57		41	191	191.48
90	86	92.34		40	196	193.67
89	88	95.00		39	199	195.89
88	89	97.55		38	202	198.15
87	91	100.02		37	206	200.45
86	94	102.41		36	210	202.79
85	97	104.73		35	211	205.17
84	98	106.99		34	219	207.60
83	101	109.20		33	220	210.07
82	103	111.37		32	224	212.60
81	107	113.49		31	228	215.18
80	110	115.58		30	231	217.82
79	114	117.63		29	233	220.53
78	118	119.66		28	241	223.31
77	121	121.66		27	245	226.16
76	122	123.64		26	246	229.10
75	**125.49**	**125.49**		25	249	232.12
74	127	127.54		24	254	235.25
73	128	129.47		23	257	238.47
72	129	131.38		22	261	241.81
71	132	133.28		21	266	245.28
70	134	135.17		20	271	248.89
69	136	137.05		19	277	252.65
68	137	138.92		18	287	256.58
67	139	140.79		17	296	260.71
66	140	142.65		16	299	265.05
65	140	144.51		15	306	269.65
64	142	146.37		14	308	274.52
63	143	148.23		13	315	279.73
62	145	150.09		12	329	285.32
61	148	151.96		11	342	291.36
60	149	153.82		10	349	297.96
59	153	155.69		9	369	305.23
58	154	157.57		8	384	313.36
57	155	159.45		7	401	322.59
56	156	161.34		6	430	333.34
55	158	163.24		5	443	346.24
54	160	165.15		4	445	362.54
53	161	167.07		3	510	384.94
52	165	169.00		2	604	421.97
51	168	170.95		1	828	537.21